GEOSYNTHETIC ROADSIDE DRAINS:

GUIDELINES FOR USE IN NEW ZEALAND

Transfund New Zealand Research Report No. 155

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AN IMPORTANT NOTE FOR THE READER

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EXECUTIVE SUMMARY

Introduction

Subsoil drainage of the road pavement and subgrade has long been recognised as important to the performance and life expectancy of road pavements. Geotextile-wrapped coarse aggregate drains with plastic drainage pipes have been used for roadside drainage. With the development of geosynthetic materials, composite drains comprising a geosynthetic core wrapped with geotextile have been increasingly used overseas over the past 20 years, and more recently in New Zealand. These drains have the potential to offer cost and time savings over traditional drains, particularly in areas where aggregate is in short supply or is costly. Geology and resource management issues make aggregates more difficult to obtain in some areas.

At present (1999) in New Zealand, only limited information is available to assist designers in the selection and specification of the most cost-effective approach to roadside drainage. It is important that the geosynthetic drains are carefully chosen, drainage systems are well designed and are installed with appropriate placement and backfilling to ensure good performance in the long term.

Research that was carried out in 1998-99, and documented in this report, considered the benefits and constraints associated with the predominant types of geosynthetic composite drains available in New Zealand. Guidance is provided for designers on the factors that need to be considered when designing, specifying, and installing geosynthetic composite drains.

A number of overseas studies, mainly in USA, have considered the performance of geosynthetic composite drains in their countries. These studies show that these drains generally perform as well as the traditional drains, provided they are designed and installed with care. The studies highlight a number of problems relating to poor installation and backfilling. The main problems identified include core collapse related to inappropriate core choice or improper installation leading to "J"ing and bending, damage during installation, settlement of trenches, and clogging of the geotextile. Poor gradients and outlets have also led to unsatisfactory performance. These problems result from poor design and installation, which have also been observed with traditional drains.

Types of Product

The geosynthetic drainage products available can be classified as those with rigid, semi-rigid and flexible cuspate cores. They are generally wrapped with a commonly used geotextile. Special orders with different geotextile wrapping can be obtained at a higher cost. While all types are suitable, the more rigid non-cuspate core drains are more robust and can withstand some installation deficiencies and also higher traffic loads. Hence they are more suitable for areas with heavy traffic loading on or adjacent to the drains.

Design Flowchart

A flowchart is provided to assist designers with consideration of the critical issues and selection and detailing of appropriate systems. The design issues include the purpose (e.g. as pavement drains or interceptor drains), likely inflow and flow capacity, soil conditions, exposure to chemicals, road edge loading, and availability of backfill materials. The construction issues requiring consideration include trench size and trenching methods, position and orientation of the drain, backfill type, method of backfilling and compaction. Adequate consideration should also be given to outlet protection, potential for erosion and fluming, where necessary.

Adequate maintenance would also help achieve long-term performance and optimum life cycle costs. This maintenance may include inspection and flushing as required, and also provision of an effective outlet for the water collected.

Although high quality aggregate backfill is not required for geosynthetic composite drains, and narrow trenches are sufficient for their installation, selection of backfill, its placement and compaction are critical to ensure satisfactory performance of the drain and the pavement. The selection, placement and compaction of backfill for the types of materials available in New Zealand (including volcanic materials, such as scoria and pumice), equipment available and construction methods all require further research.

Recommendations

1. The existing Transit New Zealand Specifications, TNZ F/2 *Pipe subsoil drain construction,* and TNZ F/6 *Fabric-wrapped aggregate subsoil drain construction,* do not recognise the range of options for methods and materials now available for roadside subsoil drains.

The recommendation arising from this research is to revise these specifications to reflect current industry trends and technology. The revised specifications should be generic, covering the range of products available, to allow the use of alternative systems, provided these meet design, construction and performance criteria, appropriate to the project.

The revised specifications should also cover installation requirements to ensure that the drains are placed and backfilled correctly.

2. Types and methods of placement and compaction of backfill appropriate for geosynthetic roadside drains in New Zealand are somewhat uncertain, and therefore the following recommendation is made.

A further stage of research comprising field construction trials should be carried out to assess the suitability of different types of backfill, in different areas in New Zealand, and to assess the placement and compaction methods. These trials should be carried out as part of real construction projects, so that the construction issues in real project situations can be assessed. This would also minimise the cost of the field trials.

ABSTRACT

Subsoil drainage of the road pavement and subgrade is important to the performance and life expectancy of road pavements. With the development of geosynthetic materials, composite drains comprising a geosynthetic core wrapped with geotextile have been increasingly used overseas over the past 20 years, and more recently in New Zealand.

Research that was carried out in 1998-99 considered the benefits and constraints associated with the predominant types of geosynthetic composite drains available in New Zealand. Guidance is provided for designers on the factors that need to be considered when designing, specifying, and installing geosynthetic composite drains. The geosynthetic drainage products may have rigid, semi-rigid or flexible cuspate cores, generally wrapped with a commonly used geotextile.

A flowchart is provided for considering design and construction issues, and for selection and detailing of appropriate systems. Recommendations are made for updating the present specifications for subsoil drain construction, and for construction trials with different types of backfill around New Zealand.

1. INTRODUCTION

Subsoil drainage of the road pavement and subgrade has long been recognised as important to the performance and life expectancy of road pavements. Appropriate design and construction are important for these drainage systems to provide adequate and reliable drainage.

Three factors require consideration during the design and construction of the subsoil drainage system so that the system can achieve its ultimate objective of assisting in the production of a stable subgrade for pavement construction:

1. The drain must be able to pass sufficient water to meet the design requirements;
2. The drain must be able to continue functioning without clogging over a long period of time; and
3. The drain must be able to withstand any loads imposed upon it in service.

Subsoil drains comprising aggregate filter material with clay pipes were previously used as roadside drains. With the introduction of plastic and geotextile products, the drains were modified to geotextile-wrapped coarse aggregate with plastic drainage pipes.

Geosynthetic composite drains comprising a geosynthetic core wrapped with geotextiles have been introduced into the market over the past 20 years. A number of types of these products are now marketed, and are claimed to be a cheaper and more efficient alternative to the predominantly used geotextile-wrapped aggregate drains.

At present (1999), little information is available to assist designers in the selection and specification of the most cost-effective approach to roadside drainage in any particular situation. The tendency is to use the known geotextile-wrapped aggregate trench drains, because of a lack of knowledge and confidence in the performance of geosynthetic composite drains. The more proactive designers may specify geosynthetic composite drains. However, in the absence of guidance, there is the risk that they may inadvertently choose an inappropriate product or not specify adequately, leading to costly problems occurring during and after construction.

This research, carried out in 1998-99, considers the benefits and constraints associated with the predominant types of geosynthetic composite drains and provides guidance to designers. The types of geosynthetic composite drains available in New Zealand are outlined and advice is provided on the factors which need to be considered when designing, specifying, and installing these drains.

Note that the inclusion of manufacturers' names and product names is for the purpose of identification of different types only and does not constitute endorsement of any products.

2. HISTORY OF USE

Traditionally, roadside edge drains were constructed using earthenware (clay) pipes laid in a trench, which was then backfilled with graded aggregate. The introduction of PVC pipes, geotextile fabrics, and latterly geosynthetic products, has brought about a variety of options for the design and installation of roadside drainage.

In France, synthetic-wrapped PVC drains were installed in the mid 1970s. In England, the use of geosynthetic drainage products was largely restricted to structures and cut-off drains until the publication of the Highway Construction Details (Department of Transport 1987). This gave standard installation details and prompted suppliers to actively market their products as edge of pavement drains (Corbett 1990).

True geosynthetic composite drains, comprising a geotextile-wrapped polyethylene (PE) or polypropylene (PP) core, were first installed in a number of US states in the early 1980s.

A trial length of just over 5 miles (8 km) of highway was constructed incorporating geotextile-wrapped aggregate drains in West Virginia in 1982. Studies after 4½ years of service indicated that the system appeared to have performed satisfactorily (Baldwin & Long 1988), though the addition of a more positive outfall system was proposed for future installations.

Recognising the growing future for geosynthetic composite drainage products when a supplier submitted their product for approval, the Indiana Department of Transportation (INDoT) introduced one of the earliest generic specifications for the installation of geosynthetic composite drains in 1986. It has made a number of revisions since that time (Smutzer et al. 1996).

A number of studies have since been carried out into the performance of geosynthetic composite drains, and the relative performance of geosynthetic composite drains compared to traditional trench drains. From a study carried out in England in the late 1980s, O'Reilly & Brennan (1989) concluded that of the 19 km of highway drains (traditional clay pipe in trench drains) surveyed in four counties, over 15% showed signs of some form of structural defect which would affect their long-term performance. The incidence of structural defects was lower in motorway drains than in local roads. Approximately 30% showed signs of faulty connections between pipes.

A major study of long-term performance of geosynthetic composite drains by Koerner et al. (1994), involved exhumation at over 90 sites in 17 states across the US. The subsequent report outlined many of the problems and solutions associated with the use of geosynthetic composite drains (Koerner et al. 1996).

In New Zealand, roadside drainage has traditionally been provided by trench drains constructed in accordance with either TNZ Specification F/2:1989, *Pipe subsoil drain construction*, or TNZ F/6:1985, *Fabric-wrapped aggregate subsoil drain construction*. Since the mid-1980s, geosynthetic composite drainage products have slowly found some use in roading projects.

A number of studies have concentrated on specific aspects associated with geosynthetic composite drains, including:

- Geotextiles and filtration properties: Hudson & East (1991).
- Geotextiles and their interaction with fine grained soils: East & High (1989), East & Hudson (1987).
- Backfill compaction: Ford & Eliason (1993).
- Installation damage to geotextiles: Koerner & Koerner (1990), Raymond & Bathurst (1990).
- Determination of appropriate filter fabric: Luettich et al. (1992), Luettich (1993), Christopher & Fischer (1992).
- Various laboratory testing techniques for determination of parameters influencing drain performance, touching on installation considerations: Murray & McGowan (1992).
- Drainage core flow capacity: Dempsey (1988) which is a study carried out in conjunction with Monsanto Company for the development of the "Hydraway" edge drain. This work was associated with the development of the INDoT specification (Smutzer et al. 1996).

3. METHODOLOGY

3.1 Contact Suppliers and Installers

In order to identify the geosynthetic composite drainage products available and being installed in New Zealand, the major suppliers and installers (i.e. contractors) were contacted for information.

The response from the suppliers was generally good with product information and supporting literature being provided, though the information supplied often had an understandable bias towards their favoured product. Generally, the suppliers are very helpful and prompt in providing information and advice.

As part of this study, contractors around New Zealand were contacted and those who responded were helpful in providing information and advice on the plant and machinery generally used in New Zealand for installation of geosynthetic composite drains. However the commercial sensitivity of any information relating to the in-place cost of the products, and to issues relating to the installation of the products, probably led to a poor overall response.

3.2 Product Review

Based on the information made available from the New Zealand suppliers, a tabulated summary has been prepared showing the products available in New Zealand (as at January 1999). Representative physical properties for the various products are given along with list prices. This table is given as Appendix 1.

3.3 Literature Review

3.3.1 TeLIS Search

The resources of TeLIS (*Te*chnical *L*ibrary and *I*nformation *S*ervice, Opus International Consultants) were employed to carry out a search of the available literature on the subject.

3.3.2 Review of Key Literature

A number of key publications identified during the literature search were reviewed in more detail to assist in the preparation of this document.

3.4 Preparation of Recommendations / Guidelines

A qualitative assessment of the information obtained from the literature search and from suppliers and installers has been carried out. From this work, the guidelines given in this document have been prepared. The project scope does not include site and laboratory testing which would be required to allow a more detailed assessment to be carried out.

4. PRODUCT REVIEW

4.1 Types of Products

In general, two types of roadside drains are available:

- Traditional trench drains, and
- Geosynthetic composite drains.

4.1.1 Traditional Trench Drains

Trench drains are the most common form of roadside drain and the most commonly installed. This type of drain is taken as the baseline for comparison purposes with geosynthetic composite drains.

The system comprises a shallow trench, generally about 600 mm to 1200 mm deep and 600 mm wide, usually (but not always) lined with geotextile material and backfilled with drainage aggregate. A perforated uPVC, polyethylene (PE) or polypropylene (PP) pipe at the base of the trench collects and carries the water to the point of discharge (Figure 4.1).

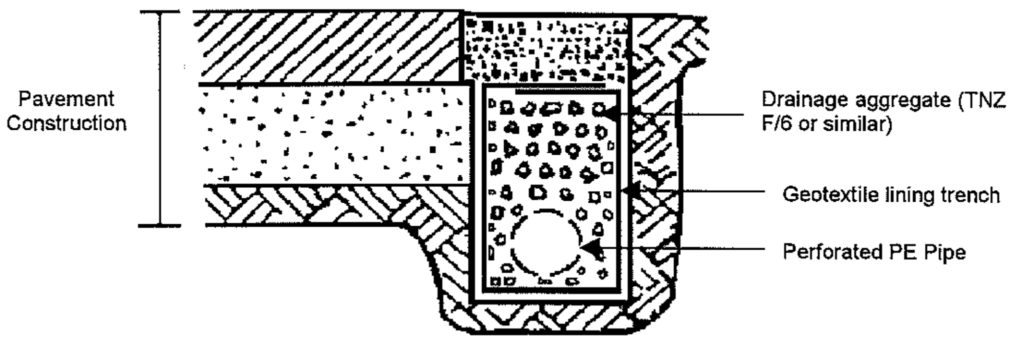


Figure 4.1 Traditional trench drain.

In New Zealand, the common practice is to use a granular filter material (such as the type specified in TNZ F/2) in conventional subsoil drains not lined with geotextile, and an open graded filter material (such as the type specified in TNZ F/6) in lined drains. Farrar & Samuel (1989) give a good description of the performance of this drain.

More recently, a modified form of trench drain has become widely used overseas, though less so in New Zealand. This is the simplest form of geosynthetic composite drain and comprises a perforated uPVC, PE or PP pipe, wrapped in a geotextile, often on site, and laid at the base of a trench filled with drainage aggregate (Figure 4.2).

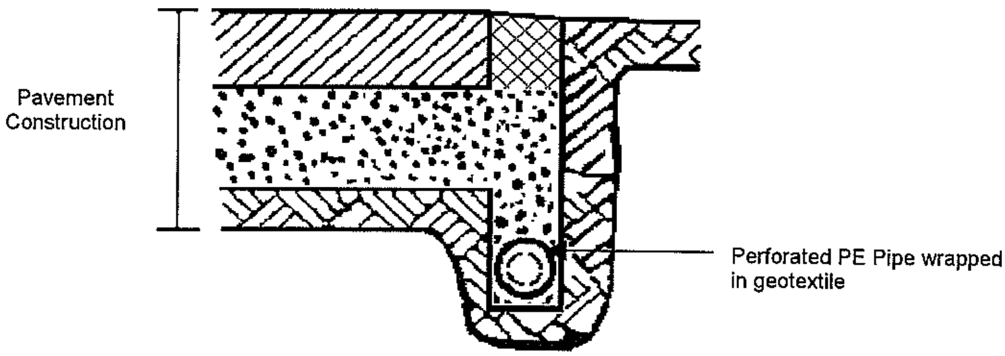


Figure 4.2 Geotextile-wrapped perforated PE drain.

4.1.2 Geosynthetic Composite Drains

Prefabricated geosynthetic composite drainage products are being used overseas more commonly today and increasingly in New Zealand. These comprise a prefabricated PE or PP core, wrapped in either a needle-punched or woven geotextile fabric depending on the product or application.

A typical cross section detail is shown in Figure 4.3. General parameters and specifications for the most common geosynthetic composite drain products currently available in New Zealand (based on supplier literature) are given in Appendix 1.

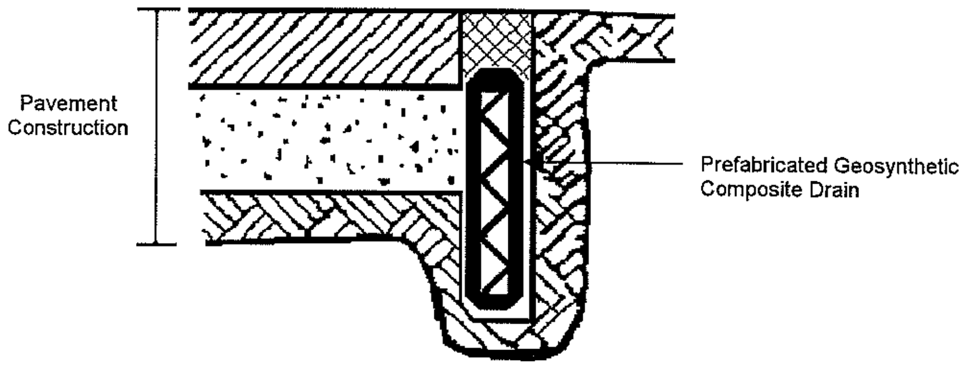


Figure 4.3 Prefabricated geosynthetic composite drain.

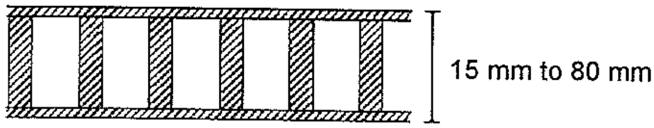
4.2 Properties

Appendix 1 lists the products available in New Zealand (as at January 1999), along with representative physical properties based on information provided by their respective New Zealand suppliers.

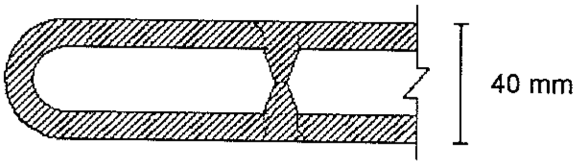
4.3 Core Construction

Prefabricated geosynthetic composite drains fall into three categories based on their core construction:

- *Rigid core*



- *Semi-rigid non-cuspate core*



- *Flexible cuspate core, either single or double cuspate*

"Thin" cores, constructed from extruded PE/PP sheets or mesh, wrapped in geotextile, are also available, but are generally not used for roadside drain applications, and are more suited for drainage adjacent to structures or under landfill/leachate liner systems.

4.4 Geotextile

The products are generally supplied prewrapped in a low to medium weight geotextile, such as Bidim A14 or Terram 1000. It is possible to get some products wrapped in alternative geotextiles at additional cost.

4.5 Cost

List prices (as at January 1999) for the various products available in New Zealand are given in Appendix 1. Discounting for larger orders is common among the larger suppliers.

Prices fluctuate often because the products are imported and there are variations in exchange rates. Some suppliers are able to source their products from a number of factories world-wide, thus reducing the impact of exchange rate variations.

4.6 Use in New Zealand

Geosynthetic composite drainage products have been used in roading projects in New Zealand since the mid 1980s, with the suppliers indicating that they have been used on a number of both large and small projects. The products are continuing to gain favour. On occasion, geosynthetic composite drains are not in the original design, but are proposed by a contractor as an alternative.

Many suppliers can provide standard installation details in CAD format, along with installation procedures and product specifications for inclusion in contract documentation.

5. DESIGN AND INSTALLATION

5.1 Design Considerations

The following eight factors must be considered during the selection process to ensure that an appropriate product is chosen for the application under consideration:

5.1.1 Situation/Function

- Pavement drains and subsoil drains (shallow drain, minimal inflows).
- Cut-off drains/interceptor drains (deeper drain, higher flows).

5.1.2 Soil Conditions

- *Fine-grained material* (weathered soils or rocks, cohesive soils, loess):

  Such soils are common in New Zealand, covering a substantial proportion of the North Island and some of the South. The TNZ F/6:1986 specification notes (TNZ 1986) suggest that further particle size analysis and permeability testing of the soil should be carried out when LL > 40, PI > 15, and/or $D_{85} < 75\mu m$. The choice of an appropriate grade of geotextile is then required to provide adequate filter characteristics.

- *Coarse material* (sands/gravels):

  Generally coarse material presents few problems, though voids in the trench walls may result in tearing or puncture damage to the geotextile during compaction of the backfill. Trench stability may be of concern, particularly with deeper drains and in coarser materials.

- *Rock:*

  The potential with excavations in rock is for tearing damage to the geotextile wrapping. Also there may be excavation difficulties (so that using a chain digger or disk cutter may need to be considered).

5.1.3 Geotextile

The primary role of the geotextile in a geocomposite drain is filtration. The geotextile must allow water to pass through the soil/fabric interface while retaining most of the soil particles without clogging.

Determination of an appropriate geotextile is important to ensure the long-term performance of the geosynthetic composite drain. Particle size analyses of the surrounding soil and the proposed backfill material would assist in selection.

For New Zealand conditions, TNZ F/6 Notes:1986 give a brief general coverage of geotextile function. East & Hudson (1987) and Hudson & East (1991) provide good overviews of geotextiles and their use, though they focus primarily on pavement construction applications.

East & High (1989) cover four common geotextiles available in New Zealand that are used for lining subsoil drains and their suitability as geotextile filters. Criteria for selection of appropriate geotextile properties for fine grained soils are given, along with suggested amendments to the TNZ F/6:1985 specification.

Corbett (1990) reported measured normal flow rates of less than a thousandth of the laboratory test rates. This suggests that, in cases where the performance of the drainage system is critical, specific testing of both soil and geotextile should be carried out. This is to allow a more accurate and reliable estimation of design properties than may be obtained from the general particle size testing and selection charts available in the product literature.

Luettich et al. (1992), Luettich (1993) and Christopher & Fischer (1992) give good reference information for the determination of appropriate geotextile parameters.

5.1.4 Flow capacity

- High groundwater levels or continuous flows (low-lying areas, strong seepages, high permeability soils). A high capacity drain is needed and a semi-rigid or rigid product is generally required.
- Fluctuating/Storm ("normal" groundwater conditions, seasonal changes, storm events).
- Low (generally dry, seepages during winter months or storms, low permeability soils). Drain capacity is generally not a major issue.

5.1.5 Chemical Factors

Chemical factors are generally site-specific and will require special consideration. The specific aspects should be discussed with suppliers and checked with the literature to ensure appropriate product selection. Aspects to consider include:

- Likelihood of petroleum/diesel spillages entering the drainage system.
- Likelihood of high temperature fluids entering the drainage system.
- Mineral deposition during the life of the system (high alkalinity groundwater causing calcification).
- Biological clogging of the geotextile filter. This is an important issue, but is very site-specific and generally associated with developments around waste disposal/treatment sites.

- Marine conditions.
- Geothermal activity can have a significant effect on the growth of algae and precipitation of minerals.

Geosynthetic composite drains use different polymers in both the core and geotextile wrap. The polyethylene (PE) or polypropylene (PP) materials used for the core and the polyester, polyethylene or polypropylene used in the geotextile wrap, found on most geosynthetic composite drain products, are resistant to moderate temperature changes and to naturally occurring acid and alkali soils. Polyethylene and polypropylene are generally resistant to chemical attack. However, hydrocarbons, chlorinated hydrocarbons and petroleum products can be absorbed by polyethylene, causing minor swelling and softening (generally less than 5% at less than 65°C). As soon as these chemicals are washed away, polyethylene assumes its original properties.

These characteristics allow the drains to be tolerant of chemical influences in roading applications under normal conditions. However, if these products are to be used where there is a high likelihood of hydrocarbon products entering the drainage system, then the resistance of the particular product should be carefully considered by the designer.

5.1.6 Road Edge Loads

The actual loads on a road edge will be dependent on the site and the likelihood of wheel loads occurring along the line of the drain. The crushing strength of the geosynthetic composite drain should be considered to determine which product would be suitable for the loads predicted.

- Where significant wheel loads are anticipated, consider using geosynthetic composite drains with a higher core crushing strength, such as a rigid or semi-rigid core product, depending on the loads.
- Where normal loads are anticipated, a semi-rigid or flexible (cuspate) core product is likely to be acceptable.

5.1.7 Availability of Backfill Materials

- No convenient local source for sand/gravel backfill or only limited supply. If this creates significant cost or distance implications for the project, a geosynthetic composite drain may offer significant savings.
- Problems with obtaining Resource Consent for borrow areas may result in cost or distance implications, making consideration of a geosynthetic composite drain more attractive.
- Re-use of excavated spoil may be a possibility when using a rocksaw/chain digger through rock, though the sharp edges of the spoil can cause potential damage to the geotextile during backfilling/compaction.

5.1.8 Construction Aspects/Equipment

- Product availability: If working on a large project, liaise with the suppliers to ensure that sufficient stock is available.

- Access constraints for plant.

5.2 Installation Issues

5.2.1 Trenching Methods

The smaller cross sectional width of geosynthetic composite drains in comparison with traditional trench drains means they can be installed in a narrower trench, typically only 150 mm to 300 mm wide. This allows smaller plant to be used, such as lighter weight excavators and chain diggers. The use of smaller lighter plant can provide savings for both Contractor and Client. In areas of harder substrata, rocksaws are often used, though these can suffer from excessive tooth wear rates in certain materials (e.g. hard sedimentary rocks and igneous rocks).

The smaller cross sectional area also results in a smaller backfill volume giving further savings, and the ease of handling/installation can lead to construction time savings.

5.2.2 Position and Orientation

The geotextile wrap of the geosynthetic composite drain should generally be placed against the upstream side of the trench to ensure best performance, i.e. the side of the trench from which the greatest inflows are anticipated.

Where trench excavation results in the formation of voids beneath the pavement caused by over-excavation or slumping of the trench wall (very likely in loose granular soils), the geosynthetic composite drain should be placed vertically against the in-situ soil. The backfill is then carefully placed between the pavement construction and the drain to ensure all voids are filled.

Failure to ensure that any voids in the trench walls are filled during backfilling of the trench can lead to:

- Damage to the core (bending, crushing) or the filter fabric (tearing, puncture) during compaction of the trench backfill when the geosynthetic composite drain may be forced into the void by the backfill.

- Creation of turbid flow conditions against the geotextile because the geotextile is not in "intimate contact" with the soil. This can allow fine particles to pass through the geotextile and settle out in the core, resulting in partial blockage. The turbid flow can also result in loss of soil from around the drain, leading to further loss of support.

Single cuspate-type core materials should be installed with the apex of the cusps facing the material to be drained. This reduces the risk of core capacity loss caused by rolling or compression of the bottom rows of cusps, i.e. "J"ing (see Section 7.3 (iv) and Figure 7.1). Supporting the geosynthetic composite drain against the trench side using pins or stakes reduces the risk of "J"ing.

5.2.3 Backfill Material and Placement

The preferred backfill material for geosynthetic composite drains is sand. The use of sand backfill is recommended by the suppliers and manufacturers, and supported by the available literature.

Sand backfill is preferred as it gives an additional filter layer between the in situ soil and the filter fabric, and appears to lessen the risk of damage from coarser granular soil or aggregate during compaction. The smaller grain size of the sand backfill also ensures that a greater number of voids in the trench walls are filled.

Two methods of sand placement are available:

- flushing sand fill into trench as a slurry; and
- dry pouring.

Flushing the sand into the trench as a slurry can give better results than dry pouring, though a number of aspects have lead some researchers (Ford & Eliason 1993) to question the benefits. In particular,

- the drainage outlets must be in place before slurry backfill can be placed,
- water runs downstream along the trench floor and saturates discharge locations, making density difficult to achieve in the backfill at these points, and
- settlement of the backfill occurs, requiring the trench to be topped up.

Figure 5.1 shows the general arrangement of equipment for placing flushed sand as drain backfill.

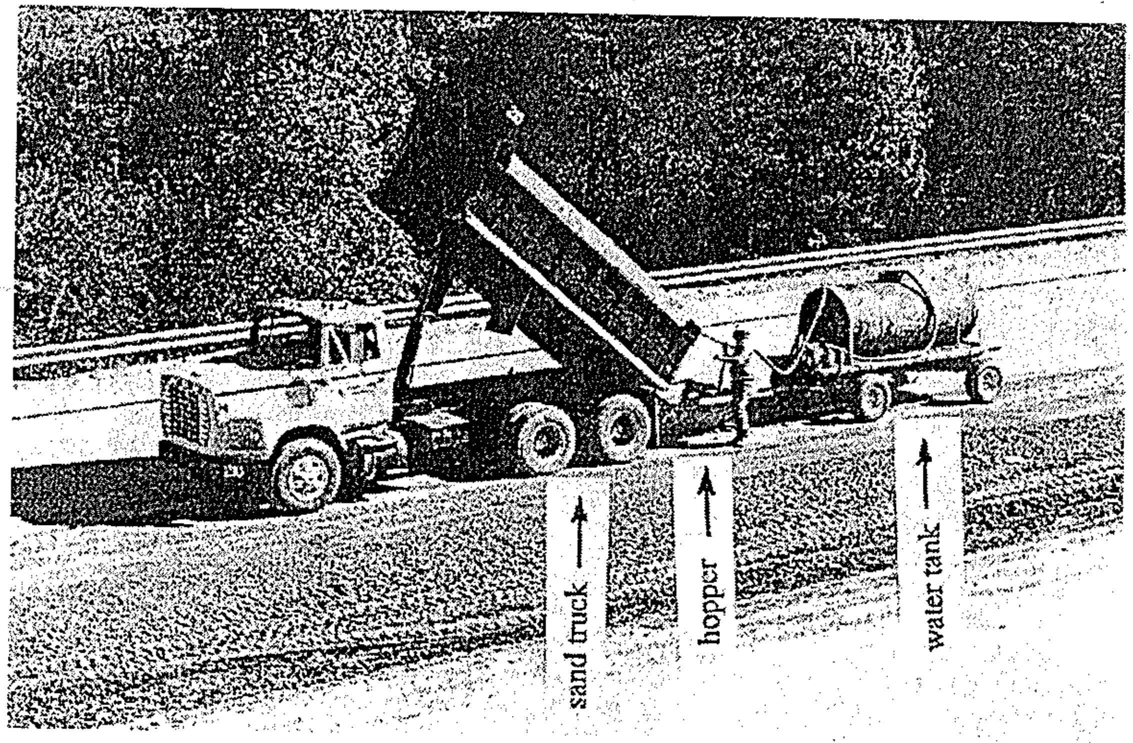


Figure 5.1 General arrangement of equipment for sand flushing.

Dry pouring has the advantage that less specialised equipment is required. However, there is a greater risk of arching occurring within the backfill, leaving voids which collapse later, resulting in trench settlement.

Graded aggregate is a commonly used alternative to sand backfill. Figure 5.2 shows the general arrangement of equipment when using a continuous operation with trenching machine and aggregate backfill equipment.

The availability and type of potential backfill materials is different in different parts of New Zealand. This requires careful consideration of backfill materials that provide efficient placement and compaction options, good performance and yet minimise cost. Also, soils such as pumice sands which are not common overseas, and about which published data are not readily available, are a potential backfill material in the Central North Island. Further research would be beneficial to assess the suitability of such different backfill materials and methods of placement and compaction.

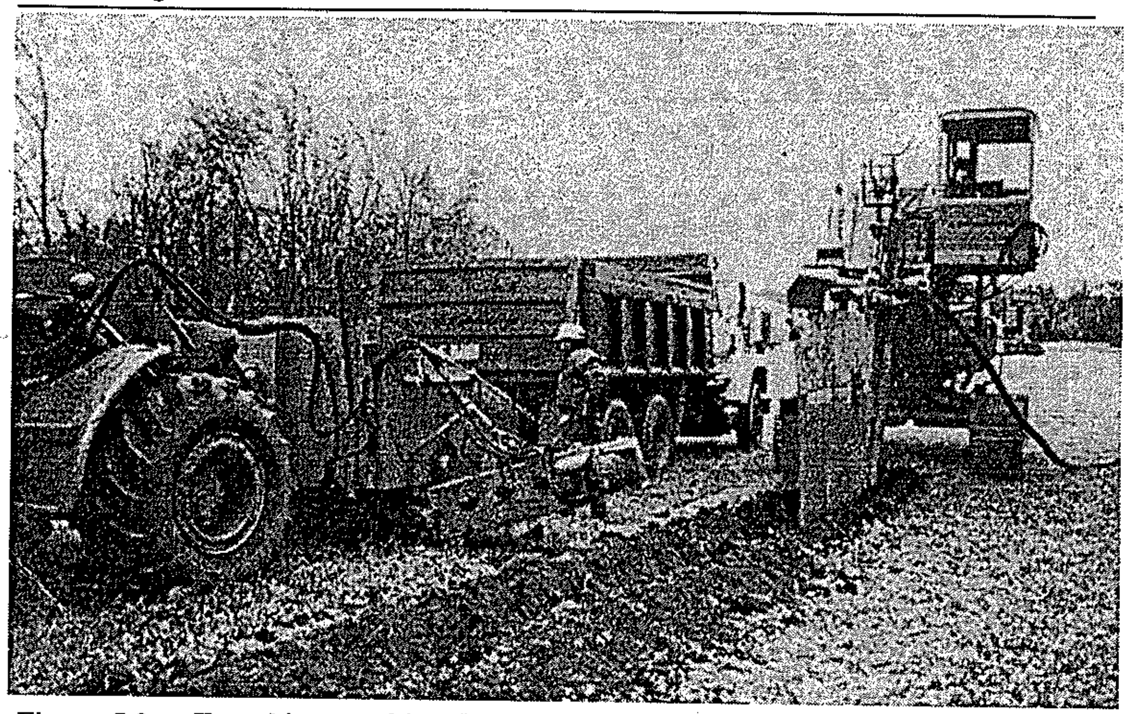


Figure 5.2 Trenching machine (DynaPac), truck delivering filter aggregate, and shouldering attachment on front end loader which places aggregate into trench (Ford & Eliason 1993).

5.2.4 Backfill Compaction

Appropriate compaction is essential to reduce settlement of the backfill material and subsequent loss of edge support for the pavement. A compaction level of about 95% of Maximum Dry Density, using Standard Compaction to NZS 4402:1986 Test 4.1.1, or equivalent) is required to minimise settlement.

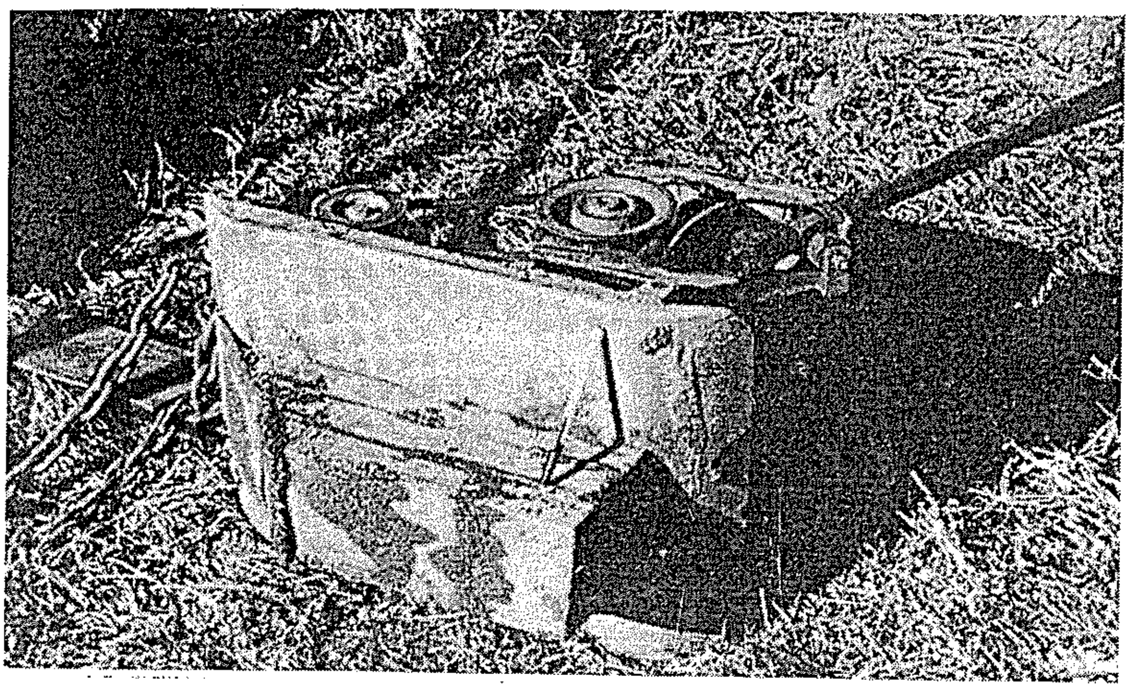


Figure 5.3 Plate compactor modified into Vibratory Ski.

Figure 5.4 Vermeer TC4a wheel compactor.

The narrower trench used for the installation of geosynthetic composite drains means that compaction of the backfill material can be more difficult. The use of a "ski" attached to the base of a plate compactor (Figure 5.3) has been used for a number of years by the Minnesota Department of Transportation, but may not give adequate compaction (Ford & Eliason 1993).

The use of more specialised equipment, such as a "wheel" compactor (e.g. Vermeer TC4a pictured in Figure 5.4) may be required. Wheel compactors can provide a greater reach and higher compactive effort than plate compactors, though are more expensive. To date, wheel compactors have not been used in New Zealand.

6. MAINTENANCE

A geosynthetic composite drain is generally a low maintenance system. Most problems that do arise are a result of poor installation or poor maintenance. Items to consider in planning a maintenance strategy include:

1. Checking for signs of post-construction settlement of the trench backfill and scheduling repairs before damage to the drain results.

2. Ensuring that drain outlets do not become blocked because of soil collapse or vegetation.

3. Checking for damage to the pipe outlet/headwall.

4. Where safety barrier posts have to be replaced following damage, ensure that the holes do not penetrate the drain.

5. Flushing the drain to maintain capacity.

6. Checking for erosion around the outlet and installing fluming where necessary.

7. COMMON ISSUES

Overseas studies indicate that, when correctly designed and installed, geosynthetic composite drains generally perform as well as traditional trench drains.

The main issues identified in these studies that will need attention in future projects to improve the performance of geosynthetic composite drains, can be divided into three categories:

- Drain core
- Geotextile characteristics
- Installation and Maintenance

7.1 Drain Core Issues

(i) *Weak core resulting in core collapse*
This generally occurs as a result of incorrect product selection because of haste or inexperience. Careful assessment of the available products is required to ensure an appropriate product is chosen for the site situation. This is also a problem in traditional subsoil drains when a weak subsoil pipe is used.

(ii) *Core collapse caused by damage during transport*
Care must be taken to inspect the material carefully before installation. Damage to the core can result from poor handling and packing during transport to the site resulting in crushing of the core. This can lead to collapse of the core and then of the drain during compaction of backfill, despite the contractor's best efforts. Damaged products should not be installed. This is also a potential issue for subsoil pipes in traditional trench drains.

(iii) *Core collapse caused by high inclined loadings during installation*
Frobel (1991) reports that problems have been encountered with collapse of drain cores caused by high inclined loadings imparted on the geosynthetic composite drain during backfill compaction. Double cuspate cores appear to be more susceptible than products with single cuspate or semi-rigid/rigid cores. This is because internal stiffness along the plane between the cusps is lacking (see cross sections in Section 4.3 of this report). Single cuspate cores with cylindrical cusps (uncommon in New Zealand) also perform poorly under inclined loading.

Care must be taken to ensure that the compaction specified is appropriate for the drainage product being proposed. Clarification should be sought from the supplier/manufacturer if there is any concern.

7.2 Geotextile Issues

(i) *Excessive clogging of the geotextile*
Clogging may be either through use of incorrect backfill materials or inappropriate filtration properties of the geotextile wrap.

(ii) *Inadequate support of trench walls during installation*
This may result in the creation of voids. The drain ends up bridging these voids so it is not in "intimate contact" with the soil. The presence of the voids can allow turbid water to contact the geotextile directly, and fine particles in suspension are then able to pass through the geotextile and settle out in the core, resulting in partial blockage.

(iii) *Clogging due to mineral deposition*

(iv) *Excessive degradation under exposure to ultra violet (UV) light*
The majority of materials available in 1999 are UV-stabilised and are generally more resistant to degradation from UV exposure than earlier materials.

These issues are also important for traditional geotextile-wrapped aggregate drains.

7.3 Installation and Maintenance Issues

(i) *Damage to drain during installation*
Installation damage is usually caused by sharp edges on core (generally only with rigid cores) or by protrusions into the trench ripping the geotextile wrap, or by bending the core itself (i.e. the core crushes, geotextile tears or both). A geotextile wrap of insufficient strength is often the cause, though poor handling and trench preparation will also contribute to the problem.

Excessive compaction can lead to collapse of the drain core (Fleckstein & Allen 1993), which has prompted many contractors to use dry or slurried sand as the backfill material.

The risk of damage can be mitigated by correct handling of the drain during installation (discuss correct handling procedures with the supplier), and checking or removing protrusions in the trench wall before drain placement.

(ii) High fines content of backfill materials

The use of backfill materials that are high in silt and clay content can lead to clogging of the geotextile around the drain core. This results in reduced filter performance and a shorter lifespan.

This problem can be avoided by using an appropriate graded-backfill material, such as sand, gravel or possibly low-fines excavated material.

(iii) Excessive post-construction settlement of the trench backfill

This is generally due to poor compaction of the trench backfill or the use of compressible material. Settlements can be controlled by:

- avoiding the use of compressible materials;
- appropriate method of placement and compaction of the backfill.

In extreme circumstances, where very little settlement can be tolerated, no-fines concrete can be used as a backfill material. However, this will be expensive and has an associated risk of geotextile clogging from cement fines.

(iv) Excessive deformation of the drain core by "J"ing or bending

"J"ing is the bottom rows of cusps rolling over, so that the rigid backing folds and compresses, leading to a loss of core capacity. This problem usually results from improper installation or excessive compaction of the backfill material.

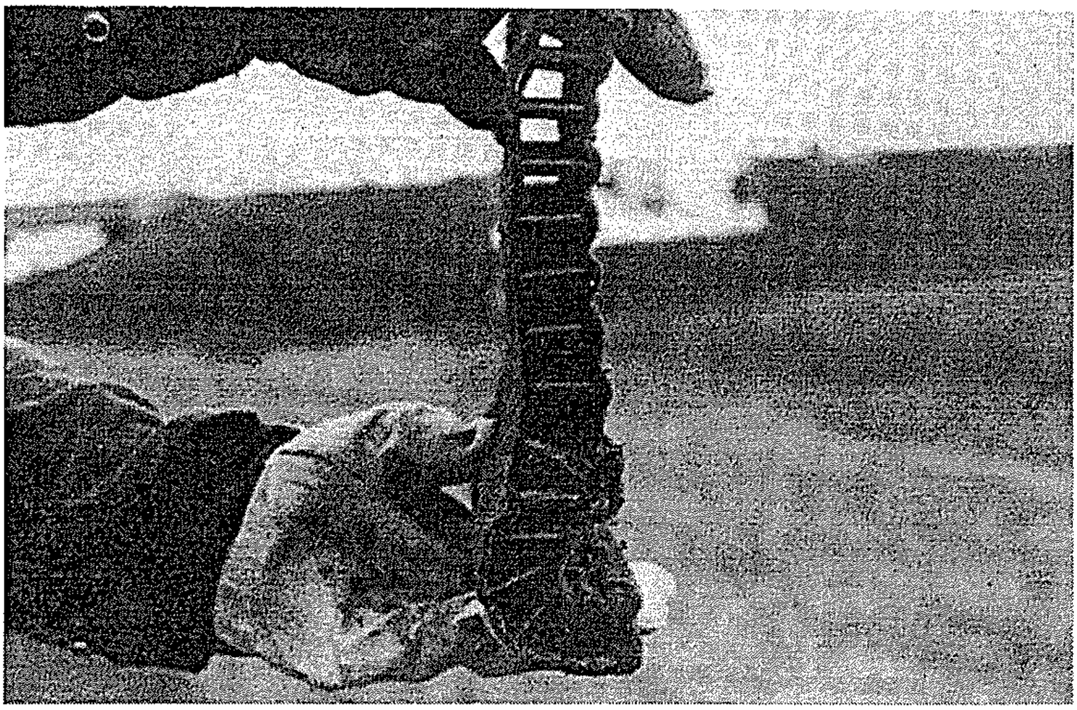


Figure 7.1 View of "J"ed single cuspate geosynthetic composite drain (note the cylindrical shape of the cusps).

"J"ing tends to be more of a problem with cuspate type cores, particularly single-sided cuspate types, which lack transverse or vertical rigidity. Either ensure that proper installation techniques are used, or change the product (use a semi-rigid or rigid core).

(v) *Poor outflow*

This occurs when the invert level is either too low relative to the outlet, resulting in either poor drainage or backflows in the drain.

Avoid this problem by designing the drainage layout with adequate gradients, checking the construction drawings for invert mismatches before plans are signed off. Then carry out adequate checks on site to ensure gradients are correct before backfilling the trenches.

Poor outflows may also be caused by sagging of the drain allowing water to stand or pond. This can occur when water is allowed to stand in the excavated trench, leading to softening of the trench floor which in turn can lead to settlement and sagging of the drain following backfill compaction. Drains should be installed and backfilled soon after excavation, or standing water must be cleared and the trench floor trimmed and re-levelled before the drain is installed.

(vi) *Blocked drain outlets caused by soil collapse or vegetation*

Ensure that the slopes at all drain outlets are stable and that vegetation is trimmed as part of regular maintenance inspections. Where necessary, flumes should be installed to direct the outfall to a stable discharge point.

(vii) *Damage to the pipe outlet /headwall structure*

Any damage to pipe outlet or headwall structures should be picked up during regular maintenance inspections.

(viii) *Location and level*

Ensure that drain is set not too high or too low relative to the pavement, nor too far from the pavement edge to be effective.

(ix) *Safety barrier post holes penetrating geosynthetic composite drain*

Check the design for possible conflicts, and ensure the set out on site is correct. Locate drain away from post holes.

(x) *Allowance for flushing*

Flushing involves pumping clean water through the geosynthetic composite drain to loosen and remove silt build-up, thus returning the drain to close to its original capacity. The flushing can be carried out using water from a nearby fire hydrant main (with appropriate approval), pumped from a tanker, or from low-pressure water-blasting equipment

Where practical, "flushing eyes" or inspection chambers should be installed to assist with long-term maintenance.

(xi) *Long-term inspection*
After about 2 to 3 years service, the geosynthetic composite drains should be inspected for signs of siltation using a borescope. If required, flushing can be considered.

8. ADVANTAGES AND DISADVANTAGES

8.1 Level of Supervision

Care must be taken to ensure that the product supplied matches that specified, particularly where a different grade of geotextile has been specified, as use of an incorrect product can lead to significantly reduced performance in the longer term. Appropriate QA (Quality assurance) procedures for both supplier and installer should avoid this problem.

A greater degree of care and supervision is required with the installation of geosynthetic composite drains than for traditional trench drains, especially with flexible geosynthetic composite drain products.

8.2 Cost

Reductions in cost for a project through the use of geosynthetic composite drain products can accrue despite the sometimes higher material costs. Cost efficiencies can accrue from a number of factors, including:

- Reduced excavation and disposal volumes because a narrower trench is required.
- The use of smaller plant.
- Less backfill is required because of the narrower trench. Thus lower backfill costs for the project and the backfill material may be easier to source because smaller volumes are required.
- The smaller volumes and ease of installation result in additional time and cost savings.

Overseas studies suggest that the overall cost of geosynthetic composite drains can be as little as one third the cost of traditional geotextile-wrapped aggregate drains.

8.3 Safety Issues

The relatively lightweight nature of geosynthetic composite drain materials allows them to be easily handled.

8.4 Flow Capacity

Manufacturers often claim that their product has a higher flow capacity than traditional TNZ F/6:1986 type drains. While this is generally true, the benefits from this extra capacity depend on whether there is a need for a higher flow capacity in a given road situation. It is also possible that the increased capacity can be obtained with a traditional TNZ F/6 type drain by careful design (e.g. use of larger pipe, more permeable drainage aggregate).

8.5 Backfill Materials

Suitable backfill materials include gravel, sand and trench spoil, though use of the latter is generally limited to sites where either the excavated spoil is fairly granular in composition, or no other materials are available.

If sourcing suitable gravel materials for trench drain backfill is difficult or expensive for a given project, the use of geosynthetic composite drains may offer an attractive solution due to the smaller backfill volume requirements resulting from the narrower trench required for installation.

8.6 Installation and Backfill Compaction

The narrower trench requires special equipment for excavation and compaction of the backfill, if the benefits are to be derived from using geosynthetic composite drains. However, this equipment is not always available in New Zealand.

9. GUIDELINES

9.1 Introduction

Geosynthetic composite drainage products have been used in civil engineering projects overseas since around 1980 and in New Zealand since the mid 1980s. Overseas studies (Koerner et al. 1994) suggest that after 10 or so years service, the performance of the products available appears to be more than adequate.

Basic guidelines for the selection and installation of geosynthetic composite drains are presented below in the form of a flowchart. Reference should be made to the relevant sections of this report, and to the references given, for background information and clarification. Notes on each step of the flowchart are given in Section 9.2.

Koerner & Hwu (1991) give an outline of a rational, rather than empirical, design approach for the selection of geosynthetic composite drains. In general, while the procedure outlined is openly specific for SE Pennsylvania (USA), the methodology could be applied in New Zealand. However, the constraints imposed by site geology, and the concerns expressed by Koerner & Hwu about the inadequacy of the geotextile wrap on a number of products, should be addressed for local conditions.

9.2 Notes on Flowchart

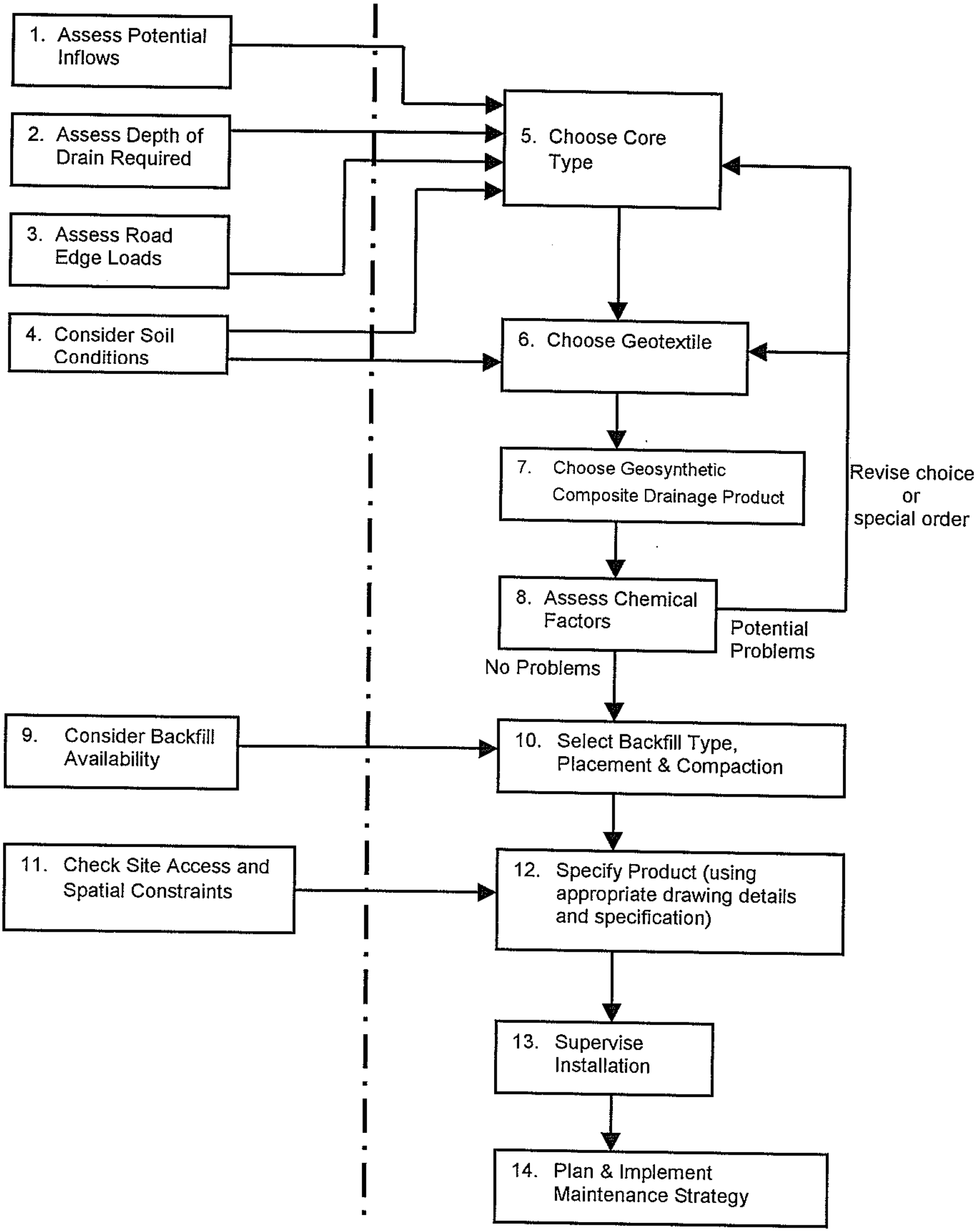
The number of the items below refer to those in the flowchart.

1. *Assess potential inflows*

   Assess the potential catchment feeding the drain.

   Consider the likely inflow and the required capacity of the drain.

   - High groundwater levels or continuous flows (low lying areas, strong seepages, high permeability soils). A high capacity drain is needed and a semi-rigid or rigid product is generally required.
   - Fluctuating/Storm ("normal" groundwater conditions, seasonal changes, storm events). Requires a moderate capacity drain. Most drain types will be suitable.
   - Low (generally dry, seepages during winter months or storms, low permeability soils). Drain capacity is generally not a major issue.



Note: For guidance on each step, refer to the notes with matching numbers in Section 9.2

Figure 9.1 Guidance for selection of geosynthetic composite drains.

2. *Assess depth of drain required*

Assess the depth to which the drain has to be installed.

Consider the required drawdown, the depth at which groundwater may be intercepted, and the role of the drain. Is it a pavement edge drain or a cut-off drain?

3. *Assess road edge loads*

High road edge loads, such as those of trucks at a weigh station, may require a rigid core product to be used, while for generally low loads, a semi-rigid core may be acceptable.

Consider the location of the drain relative to the traffic, e.g. for highway installations, and if the drain is under the edge of the pavement or behind the line of the safety barrier.

4. *Consider soil conditions*

Consider the soil conditions (material type, permeability, etc.) at the site. They will influence a number of aspects including:

- ease of excavation and selection of plant, e.g. use of chain digger or rocksaw;
- re-use of spoil as fill, e.g of excavated gravels or rock chippings;
- damage hazards during installation, e.g. formation of voids in trench walls (sands and gravels) or sharp protrusions (rock);
- fines washing in from trench sides.

5. *Choose core type*

Choose the appropriate core type for the application based on the data evaluated above and the information in Section 4.3 of this report.

6. *Choose geotextile*

Based on the soil properties and ground conditions along with the information given in Section 4.4, choose the appropriate geotextile for the application. If a standard product is not appropriate, the supplier should be contacted to see if the chosen core can be wrapped in the required geotextile.

7. *Choose geosynthetic composite drainage product*

Based on the core type and geotextile chosen above, choose a geosynthetic composite drainage product suitable for the application. The availability of a standard core/geotextile combination may influence the decision.

8. *Assess chemical factors*

Chemical factors are generally site-specific and will require special consideration. The specific aspects should be discussed with suppliers to ensure appropriate product selection. Aspects to consider include:

- Likelihood of petroleum/diesel spillages entering the drainage system.
- Likelihood of high temperature fluids entering the drainage system.
- Mineral deposition during the life of the system (high-alkalinity groundwater causing calcification).
- Geothermal activity, which can have a significant effect on the growth of algae and precipitation of minerals.
- Marine conditions.
- Biological clogging of the geotextile filter. This is an important issue, but is very site-specific, generally associated with developments around waste disposal and treatment sites.

Consider the likely influence of these factors on the performance of the chosen product. If there is a problem, then discuss with the supplier and reconsider.

9. *Consider backfill availability*

Consider the availability of backfill materials, because a geosynthetic composite drain may offer significant savings over a backfill that involves long distance haulage.

At some sites, there may not be a convenient local source for sand/gravel backfill, or there may only be a limited supply.

Minimise the required trench width where possible to reduce the required volume of backfill.

Give consideration to obtaining Resource Consent for borrow areas if a suitable source of material can be identified.

If excavation by rocksaw or chain digger is being considered, the chippings may be suitable for use as backfill, though their sharp edges can cause damage problems during backfilling and compaction.

10. *Select backfill type, placement & compaction*

Select the backfill material (sand, gravel, or possibly excavated material) and the method of placement (flushing, dry pouring, any specialised equipment required) and compaction (plate compactor, wheel compactor).

11. *Check site access & spatial constraints*

Consider the likely influence of the site location on the installation of the chosen product. For instance:

- Tight spatial constraints may influence the drain layout and hence product selection, as rigid core products may be difficult to handle in some situations.
- If the site is remote, consider the cost of mobilising specialist installation equipment. Also consider access, and ease of getting plant to the site.
- Consider product availability: if working on a large project, liaise with the suppliers to ensure that sufficient stock is available.

12. *Specify product (using appropriate drawing details & specification)*

Having chosen the product, ensure that it is correctly specified in the construction drawings and contract documentation. Many suppliers can provide standard installation details in CAD format, along with installation procedures and product specifications for inclusion in contract documents. In many instances, generic specification may be appropriate.

13. *Supervise installation*

Supervision of the installation is very important. Most problems with geosynthetic composite drains arise through poor installation.

Ensure that the supervisory staff and contractors are fully conversant with the product and the required method of installation.

Appropriate QA procedures and installation specifications are an advantage. The supplier's representatives may be able to assist with installation procedures and/or on-site training.

14. *Plan & implement Maintenance Strategy*

While geosynthetic composite drains require only minimal maintenance, a planned maintenance strategy can assist in prolonging their useful life.

Therefore consider:

- Scheduling regular inspections of the drainage system.
- Checking for signs of post-construction settlement of the trench backfill, and scheduling repairs before damage to the drain results.
- Ensuring that drain outlets do not become blocked because of soil collapse or vegetation.
- Checking for damage to the pipe outlet /headwall.
- Ensuring that, where safety barrier posts have to be replaced following damage, the holes do not penetrate the drain.
- Flushing of the drain to maintain capacity.
- Checking for erosion around the outlet and installing fluming where necessary.

10. RECOMMENDATIONS

10.1 Revision of Specifications

The existing Transit New Zealand Specifications F/2:1989 and F/6:1985 provide recommendations for roadside drains to use on state highways in New Zealand. These specifications do not recognise the range of options for methods and materials that are now available for roadside drain construction, and are somewhat outdated. The recommendation obtained from this research is to revise these specifications to reflect current industry trends and technology.

The revised specifications should be generic, covering the range of products available, and be presented in a format that is suitable for specification of project-specific requirements. The revised specifications will allow contractors to use alternative systems, provided these meet design, construction and performance criteria, appropriate to the project.

The revised specifications should also cover installation requirements to ensure that the drains are placed and backfilled correctly.

The TNZ Specifications are widely used and would provide a good vehicle to achieve consistency in both specification and construction standards, and hence performance. Since these specifications are widely used in the civil engineering industry, if revised they will serve to facilitate more use of appropriate drains in projects. Thus the associated benefits to the industry could be realised more quickly.

Revision and updating of the relevant sections of Transit New Zealand Research Report No. 6 (Hudson & East 1991) is also recommended.

10.2 Construction Trials

Types and methods of placement and compaction of backfill that are appropriate to geosynthetic roadside drains for New Zealand roads are somewhat uncertain, considering the different types of backfill and limitations of their availability. Also the types of equipment available and in use in New Zealand are somewhat different from those used in other parts of the world where most research has been concentrated to date. Given the relatively small road construction market, these factors may not improve in the short term, and perhaps even in the medium term.

Therefore, the recommendation of this research is that further study in the form of construction trials should be carried out to assess the suitability of different types of backfill in different areas in New Zealand, and to assess the placement and compaction methods.

These trials should be carried out as part of real construction projects, so that the construction issues in real project situations can be assessed. This would also minimise the cost of such field trials.

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Details of Geosynthetic Composite Drain Products Currently Available in New Zealand (as at January 1999)

Drain Type	Product	Construction	Nominal Product Sizes	Nominal Capacity @ 1% grade (l/min/m)	Crush strength (kN/m^2)	Geotextile CBR Burst Strength (AS3706.4) (N)	Geotextile Pore Size (AS3706.7) (O_{95} in μm)	Cost per m run (ex GST) (excluding backfill)
Traditional Geotextile Wrapped Aggregate Drain								
	Generic	Drainage aggregate wrapped in geotextile, perforated PE or PP pipe at base	Varies, generally 900 mm D 300 mm W	-	-	Depends on geotextile chosen		Approx, $6.50
Rigid Core								
	Atlantis Strip Filter Drain	Recycled polypropylene (PP) core, non woven polypropylene (PP) geotextile wrap (Kiaratex KE20)	100 mm D 80 mm W 4700 mm Lengths	120	120	3500 (to DIN 54307) (Kiaratex KE20)	150 (Kiaratex KE20)	$5.50
	Atlantis Strip drain (fabricated from lengths of Atlantis Drainage Cell)	Recycled polypropylene (PP) core, non woven polypropylene (PP) geotextile wrap (Kiaratex KE20)	150 mm D 30 mm W 3600 mm Lengths (see Note 1)	13	780	3500 (to DIN 54307) (Kiaratex KE20)	150 (Kiaratex KE20)	$4.20 (100 x 30mm) $5.45 (150 x 30 mm) $7.40 (200 x 30 mm) $10.70 (300 x 30 mm) $13.75 (400 x 30 mm)
	Nordrain	Recycled polypropylene (PP) core, non woven needle punched polypropylene (PP) geotextile wrap (Syntex 401)	336 mm D 30 mm W 2000 mm lengths	315	1400	1890 (to BS6906/4) (Syntex 401)	150 (to ASTM D4751) (Syntex 401)	$20.00
Semi-Rigid Non-cuspate Core								
	Megaflo	Polyethylene (HDPE) Core, Polyester non woven, continuous filament, needle punched geotextile wrap (Bidim A14)	150 mm, 300 mm, 450 mm & 900 mm x 40 mm thick	60 (150 mm 120 (300 mm) 200 (450 mm) 300 (900 mm)	> 200	> 1800 (Bidim A14)	< 230 (Bidim A14)	$5.30 (150 mm) $9.90 (300 mm) $14.40 (450 mm) $26.50 (900 mm)
Flexible Cuspate Core								
	Stripdrain (Double Sided Cuspate)	Polyethylene (HDPE) core, Thermal bonded, polyethylene/polypropylene (PE/PP), non woven geotextile wrap (Terram T1000-N)	100 mm to 900 mm x 40 mm thick 50 m roll	13 (100 mm) 26 (200 mm) 40 (300 mm) 70 (500 mm) 130 (700 mm)	200	1300 (Terram T1000-N)	130 (Terram T1000-N)	$4.75 (100 mm) $7.00 (200 mm) $10.15 (300 mm) $14.20 (500 mm) $30.00 (900 mm)
	Stripdrain XS (Single Sided Cuspate)	Polyethylene (HDPE) core, Thermal bonded, polyethylene/polypropylene (PE/PP), non woven geotextile wrap (Terram T1000-N)	100 mm to 700 mm x 25 mm thick 50 m roll	11 (100 mm) 23 (200 mm) 35 (300 mm) 60 (500 mm) 110 (700 mm)	300	1300 (Terram T1000-N)	130 (Terram T1000-N)	$7.30 (300 x 25mm) $11.80 (450 x 25 mm) $14.50 (600 x 25 mm) $18.30 (750 x 25 mm) $22.80 (900 x 25 mm)

Notes:
1. Smallest sizes quoted, different sizes available as "Atlantis Drainage Logs" from supplier on request.
2. Retail list price details from suppliers.